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A BAYESIAN APPROACH FOR TIMING THE NEOLITHIZATION IN MEDITERRANEAN IBERIA

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ABSTRACT. In this paper, we compile recent ^{14}C dates related to the Neolithic transition in Mediterranean Iberia and present a Bayesian chronological approach for testing the *dual model*, a mixed model proposed to explain the spread of farming and husbandry processes in eastern Iberia. The dual model postulates the coexistence of agricultural pioneers and indigenous Mesolithic foraging groups in the Middle Holocene. We test this general model with more regional models of four geographical areas (Northeast, Upper, and Middle Ebro Valley, and Eastern and South/Southeastern regions) and present a filtered summed probability of all ^{14}C dates known in the region in order to compare socioecological dynamics over a long period. Finally, we discuss the results and analyze how certain specific characteristics of sites and their chronologies can serve for timing the Neolithic expansion in Mediterranean Iberia.

KEYWORDS: Bayesian chronology, Mediterranean Iberia, Neolithization process, SCDPD, socioecological dynamics.

INTRODUCTION

The study of the Neolithic transition around the Mediterranean has given rise to a long-standing debate about the key drivers of change, involving explanations largely rooted in cultural diffusion theory and differentially emphasizing demic and/or indigenous components. Building on the pioneer work of Anmerman and Cavalli Sforza (1984), current literature presents research on the Neolithic spread at both pan-Mediterranean and regional scales, assessed against various compilations (filtered or unfiltered) of available radiocarbon datasets (Zilhao 2001, 2011; Manen and Sabatier 2003; Fort 2012; Bernabeu and Martí 2014; Isern et al. 2014).

The great increase in the number of radiocarbon (^{14}C) dates in recent years, together with the more accurate selection of samples—thanks to advances in accelerator mass spectrometry (AMS) techniques and the introduction of filters to control the quality of the samples—is providing a more robust chronological framework to support this work. This is the case in Iberia, where a notable growth of ^{14}C dates supplies the basis for exploring alternative hypotheses proposed to account for the spread of farming using Bayesian models for understanding the timing of the Neolithic transition.

In this paper, we use Bayesian chronology models to evaluate the *dual model* suggested to explain the appearance of the Neolithic in the Valencia region—the Eastern Mediterranean area of the Iberian Peninsula (Figure 1; Bernabeu 2002; Juan Cabanilles and Martí 2002; Bernabeu and Martí 2014). The dual model combines demic spread of Neolithic farmers with the possibility of contact between Neolithic settlers and Mesolithic groups in a way similar to what has been proposed in northern Europe (Zvelevil and Rowley Conwy 1986). The scenario postulates the coexistence of some pioneer Neolithic settlers with the Final Mesolithic groups in different territories during an indeterminate temporal interval.

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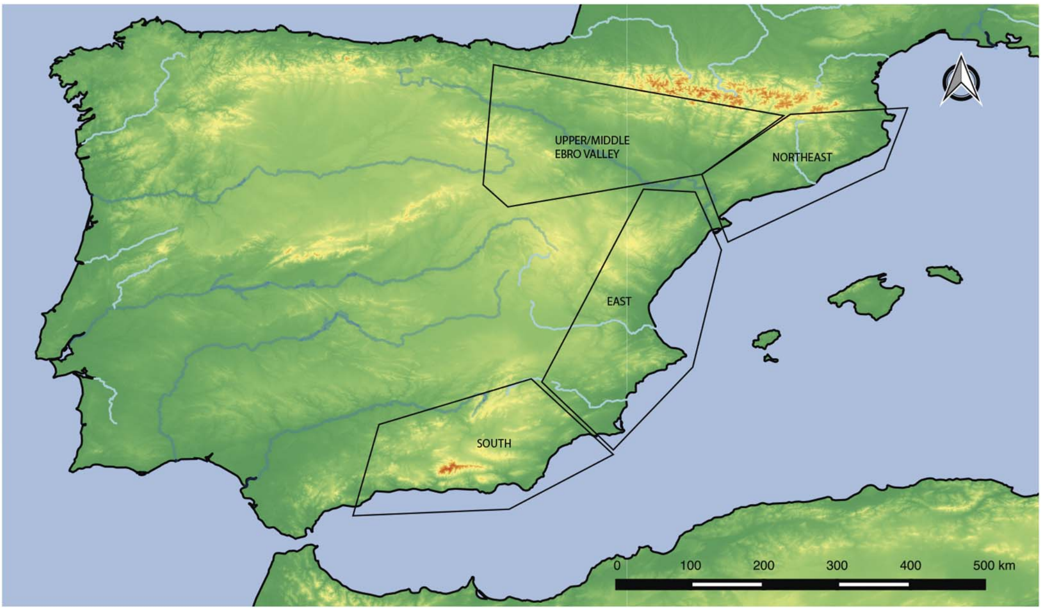

Figure 1 Map of Iberia showing the regions discussed.

To test this model, we built a Bayesian framework with accurate ^{14}C dates taken from a carefully assessed archaeological context. We use the Bayesian chronological models that have been created by OxCal developers (Bronk Ramsey 2000, Bronk Ramsey 2009). As a complementary approach, we have used summed ^{14}C probability distributions (SCDPD) to observe fluctuations in population dynamics following assumptions well explained in several key contributions (Shennan and Edinborough 2007; Shennan et al. 2013). We filtered the ^{14}C dataset in order to produce a more accurate chronology that allows us to distinguish economic patterns (foragers or producers) within a well-defined chrono-cultural context.

As a first step, we compiled all the available ^{14}C data, and then selected only single fragment samples from short-life plant and animal taxa to include in the analysis. Within the general area of Mediterranean Spain, we examine the evidence from several sub-regions in order to compare chronological models at different geographical scales.

Archaeological Background

Mediterranean Iberia is a wide region with a varied terrain of littoral planes and mountainous regions, transected by two main natural corridors for human travel: the Mediterranean coast (N/S) and the Ebro valley (E/W) (Figure 1). With generally temperate weather conditions (though varying by latitude and altitude) charcoal and pollen analyses reveal the progressive increase of forest cover since the beginning of the Holocene period, reflected by the expansion of oak and the upward migration of *Pinus sp* and *Juniperus sp* (Carrión et al. 2010). Holocene sea-level rise was a major factor in modifying the littoral landscape. Early Mesolithic settlements are well known, although the evidence is not uniformly distributed, concentrated in some areas and absent from others. The Early Mesolithic lithic industry is based on flakes, with notches and denticulates, and extends over a long period (ca. 8100–6800 cal BC) in the territory between Catalonia, the Ebro valley, and the Valencian region (Alday 2006). Evidence from the Andalusian region is not currently included in this techno-typological complex.

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Mesolithic subsistence included a wide spectrum of medium and small mammals, wild plants, and terrestrial and marine mollusks. Although cave and rock-shelter sites are common, an increasing number of open-air sites are being identified, sometimes including necropoli such as El Collado (Aparicio 2008; Gibaja et al. 2015). Coincident with the arrival of the Atlantic Period, from the middle of the 7th millennium cal BC, an abrupt change in lithic industries can be observed. They include standardized bladelets employed to make geometric microliths using the microburin technique. Regionally, this is termed the Late/Final Mesolithic or Geometric Mesolithic. Within this tradition, geographic variation is observed, such as the absence of Geometric Mesolithic assemblages in Catalonia (Vaquero and García Argüelles 2009) and the scarcity of evidence in Andalusia (Aura et al. 2013). On the other hand, the Ebro valley and the central (Valencian) portion of Mediterranean Spain show an increased number of sites in caves and rock shelters, and open air sites, although not all have been studied nor are all well preserved. Coastal-interior seasonal movement seems to characterize the subsistence strategy in the Valencian region (Martí et al. 2009), while Mediterranean links are evident in the presence of marine shells (*Columbella rustica*) at several sites located in the upper Ebro valley.

Two main phases can be recognized with some distinctive regional features. In the first phase (second half of the 7th millennium cal BC) trapeze forms predominate among geometrics, whereas triangular forms (Cocina type triangles) are more common in the second phase (first half of the 6th millennium cal BC). Around 5650 cal BC some archaeological deposits first show evidence of domesticates, together with some new cultural material such as pottery, within the Mediterranean Impressed Ware tradition (see Bernabeu and Martí 2014). Recently, new discoveries indicate the possibility of at least two independent trajectories of Neolithic colonization or influence to the Mediterranean Iberian Peninsula (Bernabeu and Martí 2014). This new information may also reveal different temporal rhythms in Neolithic expansion, as well as possible different routes (Manen et al. 2007, García Borja et al. 2014). As we show below, several chronological patterns can be observed in relation to the transition to farming throughout this large area, and we explore their possibilities by applying SCDPD and Bayesian chronological models.

MATERIAL AND METHODS

Assessment of ^{14}C Dataset

As stated above, we compiled all available ^{14}C data for Iberia between 7650 and 6000 uncalibrated BP (ca. 6600/5000 cal BC). This time span covers the Late/Final Mesolithic and Early Neolithic periods in Mediterranean Iberia. The resulting database was designed to also collect relevant information regarding the spatial and cultural context of each published ^{14}C date. For constructing Bayesian chronological models, we work only with dates taken from short-lived, single-fragment samples, with SD <100, in order to establish a more accurate approximation of the chronology of archaeological deposits (Table 1). Several studies have pointed out the potentially problematic effects of using ^{14}C dates from all contexts for estimating the timing of the Neolithic expansion in the Western Mediterranean (Zilhao 2001; Bernabeu 2006), particularly the old-wood effect that can produce anomalously older dates. In addition, problems related to the absence of an accurate sample selection protocol have been observed in multicomponent sites (Bernabeu et al. 2001; Bernabeu 2006). We also discarded samples of marine origin because the reservoir effect can be problematic, and fluctuates in relation to space and time (e.g., Ascough et al. 2005). Given these considerations, we use only short-lived, single-fragment samples (animal bones, human bones, seeds and fruits, bone artifacts, and charcoal

Table 1 Radiocarbon dates (short-life, singular samples) used to build the chronological models. A: area, PH: phase, GM: Geometric Mesolithic; EN: Early Neolithic.

Site	Area	IDLAB	BP	SD	$\delta^{13}C$	Phase	Material	Kind	Reference
Cueva de la Cocina	East	Beta267440	7610	40		GM	Animal bone	*Capra pyrenaica*	Juan Cabanilles and García 2013
Cueva de Nerja	South	GifA102010	7610	90		GM	Seed/fruit	Pine nut	Aura et al. 2013
Botiqueria dels Moros	East	GrA13265	7600	50		GM	Animal bone	*Cervus elaphus*	Utrilla et al. 2009
Abric de la Falguera	East	AA59519	7526	44		GM	Seed/fruit	Bractea	Juan Cabanilles and García 2013
Cueva de Nerja	South	Beta284148	7490	40		GM	Seed/fruit	Pine nut	Aura et al. 2013
Atxoste	Ebro	GrA13469	7480	50		GM	Animal bone		Utrilla et al. 2013
Abric de la Falguera	East	AA2295	7410	70		GM	Semilla/fruto	*Olea*	Juan Cabanilles and García 2013
Abric de la Falguera	East	Beta267441	7380	40		GM	Animal bone	*Cervus elaphus*	Juan Cabanilles and García 2013
Cueva de la Cocina	East	Beta267438	7350	40		GM	Animal bone	*Capra pyrenaica*	Juan Cabanilles and García 2013
Atxoste	Ebro	GrA13418	7340	50		GM	Animal bone		Utrilla et al. 2009
Mendandia	Ebro	Ua34366	7265	60		GM	Animal bone	*Bos primigenius*	Utrilla et al. 2009
Rambla Legunova	Ebro	GrA61768	7260	45		GM	Animal bone		Montes et al. 2015
Cueva de Nerja	South	Beta284146	7150	40		GM	Charcoal Short	*Lathirus sp*	Aura et al. 2013
Forcas II	Ebro	Beta250944	7150	40		GM	Animal bone		Utrilla et al. 2009
Atxoste	Ebro	A*3	7140	50		GM	Animal bone		Utrilla et al. 2009
Casa Corona	East	OxAV239292	7116	32	–19.5	GM	Human bone	Human bone	Fernández López et al. 2013
Cueva de la Cocina	East	Beta267436	7080	50		GM	Animal bone	*Capra pyrenaica*	Juan Cabanilles and García 2013
Casa Corona	East	Beta272856	7070	40	–19.3	GM	Human bone	Human bone	Fernández López et al. 2013
Cueva de la Cocina	East	Beta267437	7050	50		GM	Animal bone	*Capra pyrenaica*	Juan Cabanilles and García 2013
Valcervera	Ebro	GrA45763	7035	45		GM	Animal bone		Montes et al. 2015
Cingle del Mas Nou	East	Beta170714	7010	40		GM	Human bone	Human bone	Martí et al. 2009
Forcas II	Ebro	Beta290932	7000	40		GM	Animal bone		Montes et al. 2015
Valcervera	Ebro	GrA45783	6995	40		GM	Animal bone		Montes et al. 2015
Cueva del Lagrimal	East	Beta249933	6990	50		GM	Animal bone	*Capra Ibex*	Fernández López and Gómez 2009
Atxoste	Ebro	A*2	6970	40		GM	Animal bone		Utrilla et al. 2009
Esplugón	Ebro	Beta306723	6950	50		GM	Animal bone		Utrilla et al. 2012
Atxoste	Ebro	GrA13415	6940	40		GM	Animal bone		Utrilla et al. 2009
Cingle del Mas Nou	East	OxA236029	6925	35	–17.5	GM	Human bone	Human bone	Salazar García et al. 2014
Cingle del Mas Nou	East	Beta170715	6920	40		GM	Human bone	Human bone	Martí et al. 2009
Cingle del Mas Nou	East	OxA236028	6897	34	–18.4	GM	Human bone	Human bone	Salazar García et al. 2014
Cueva de la Cocina	East	Beta267435	6840	50		GM	Animal bone	*Capra pyrenaica*	Juan Cabanilles and García 2013
Botiqueria dels Moros	East	GrA13267	6830	50		GM	Animal bone		Utrilla et al. 2009
Cingle Mas Cremat	East	Beta232341	6800	50	–24.5	GM	Seed/fruit	*Corylus*	Rojo et al. 2012
Cingle Mas Cremat	East	Beta232342	6780	50	–23.0	GM	Seed/fruit	*Corylus*	Rojo et al. 2012

Cueva de la Cocina	East	Beta267439	6760	40		GM	Animal bone	*Capra pyrenaica*	Juan Cabanilles an García 2013
Forcas II	Ebro	Beta247404	6750	40		GM	Animal bone		Utrilla et al. 2009
Cariguela	South	Col1565	6749	39		EN	Animal bone	*Bos taurus*	Medved 2013
Forcas II	Ebro	Beta247405	6740	40		GM	Animal bone		Utrilla et al. 2009
Esplugon	Ebro	Beta313517	6730	40		GM	Animal bone		Utrilla et al. 2012
Peña Larga	Ebro	Beta242783	6720	40		EN	Animal bone	Ovis/capra	Fernandez Eraso 2011
Atxoste	Ebro	A*1	6710	50		GM	Animal bone		Utrilla et al. 2009
Cova d'en Pardo	East	Beta231880	6660	40		EN	Animal bone	*Capra pyrenaica*	Soler et al. 2013
Les Guixeres	Northeast	OxA26068	6655	45	−19.3	EN	Animal bone	*Ovis Aries*	Oms et al. 2014
Cova d'en Pardo	East	Beta231879	6610	40		EN	Animal bone	*Ovis Aries*	Soler et al. 2013
Aizpea	Ebro	GrA779	6600	50		GM	Human bone	Human bone	Utrilla et al. 2009
Mas d'Is	East	Beta239378	6600	40		EN	Charcoal Short	*Monocotiledonia*	Molina et al. 2011
Mas d'Is	East	Beta162092	6600	50	−24.1	EN	Seed/fruit	*Hordeum*	Bernabeu et al. 2014
Mas d'Is	East	Beta166727	6600	50	−22.7	EN	Seed/fruit	Cereal	Bernabeu et al. 2014
Cueva de Nerja	South	Beta131577	6590	40		EN	Animal bone	*Ovis Aries*	Aura et al. 2013
Chaves	Ebro	GrA38022	6580	35		EN	Animal bone	*Ovis Aries*	Baldellou 2012
Valmayor XI	East	Beta341168	6570	30		GM?	Animal bone		Rojo et al. 2015
El Cavet	Northeast	OxA26061	6536	36	−24.3	EN	Seed/fruit	*Triticum aestivum*	Martins et al. 2015
Abric de la Falguera	East	Beta142289	6510	80		EN	Seed/fruit	*Triticum monococcum*	Juan Cabanilles and García 2013
Cova de les Cendres	East	Beta239377	6510	40		EN	Animal bone	*Ovis Aries*	Bernabeu and Molina 2009
El Barranquet	East	Beta221431	6510	50		EN	Animal bone	*Ovis Aries*	Bernabeu et al 2009
El Barranquet	East	Beta239379	6510	50		EN	Animal bone		Bernabeu et al 2009
Cova de la Sarsa	East	OxA26076	6506	32	−19.8	EN	Animal bone	*Ovis Aries*	García Borja et al. 2012
Cova de les Cendres	East	GifA101360	6490	90		EN	Seed/fruit	*Triticum dicoccum*	Bernabeu and Molina 2009
La Serreta	Northeast	Beta280862	6490	40		EN	Charcoal Short	*Arbustus Unedo*	Oms et al. 2014
Cariguela	South	Col1566	6482	39		EN	Animal bone	Ovis/capra	Medved 2013
Cova de l'Or	East	UCIAMS66316	6475	25	−20.0	EN	Animal bone	*Ovis Aries*	Martí 2011
Chaves	Ebro	UCIAMS66317	6470	25	−19.9	EN	Animal bone	Ovis A	Baldellou 2011
Serrat del Pont	Northeast	Beta172521	6470	40		EN	Animal bone	*Sus Scrofa*	Rojo et al. 2012
Cueva de Nerja	South	OxA26086	6466	33		EN	Animal bone	*Ovis/capra*	Aura et al. 2013
Les Guixeres	Northeast	OxA26069	6458	38	−19.1	EN	Animal bone	*Ovis Aries*	Oms et al. 2014
Plaça Vila de Madrid	Northeast	Beta18271	6440	40		EN	Human bone	Human bone	Rojo et al. 2012
El Cavet	Northeast	OxA25802	6440	40	−24.3	EN	Seed/fruit	*Triticum aestivum*	Martins et al. 2015
Toll	Northeast	OxA26070	6425	35	−20.1	EN	Animal bone	*Ovis Aries*	Cebrià et al. 2014
Can Sadurní	Northeast	OxA15488	6421	34		EN	Seed/fruit	*Triticum dicoccum*	Cebrià et al. 2014
Cova de la Sarsa	East	OxA26075	6420	32	−18.5	EN	Animal bone	*Ovis Aries*	García Borja et al. 2012
La Serreta	Northeast	Beta280866	6420	40		EN	Charcoal Short	*Arbustus Unedo*	Oms et al. 2014
Cova Fosca Vall d'Ebo	East	OxA26047	6413	33	−18.3	EN	Animal bone	*Ovis Aries*	García Borja et al. 2012
La Serreta	Northeast	Beta280860	6410	40		EN	Charcoal Short	*Angiosperma*	Oms et al. 2014

Table 1 (*Continued*)

Site	Area	IDLAB	BP	SD	$\delta^{13}C$	Phase	Material	Kind	Reference
La Lampara	Ebro	KIA21347	6407	34		EN	Animal bone		Rojo et al. 2012
Can Roqueta	Northeast	Beta	6400	50		EN	Animal bone	*Ovis Aries*	Cebrià et al. 2014
Cova de la Sarsa	East	OxA236025	6399	35		EN	Animal bone	*Bos taurus*	García Borja et al. 2012
Can Sadurní	Northeast	OxA15489	6391	34		EN	Seed/fruit	*Triticum dicoccum*	Blasco et al 2011
Abrigo de Ángel 2	East	Beta254048	6390	40		EN?	Animal bone		Utrilla et al. 2009
Toll	Northeast	OxA26071	6390	34	−20.0	EN	Animal bone	*Ovis Aries*	Cebrià et al. 2014
Cova de la Sarsa	East	OxA236022	6389	33		EN	Animal bone	*Bos taurus*	García Borja et al. 2012
Chaves	Ebro	GrA28341	6380	40		EN	Seed/fruit	*Acorn*	Utrilla et al. 2009
Can Sadurní	Northeast	OxA15491	6375	34		EN	Seed/fruit	*Triticum dicoccum*	Blasco et al 2011
La Revilla del Campo	Ebro	KIA21358	6365	36		EN	Animal bone		Rojo et al. 2012
Cova de l'Or	East	MAMS19063	6356	23		EN	Seed/fruit		Olalde et al. 2015
La Revilla del Campo	Ebro	KIA21356	6355	30		EN	Animal bone	Ovis/capra	Rojo et al. 2012
Cariguela	South	Col1560	6350	32		EN	Animal bone	Ovis	Medved 2013
Cueva de Nerja	South	OxA26085	6342	37	−18.6	EN	Animal bone	Ovis/capra	Aura et al. 2013
Cova de la Sarsa	East	OxA239226	6341	30		EN	Cereal	Human Bone	García Borja et al. 2012
Cova de l'Or	East	Beta298125	6340	40		EN	Seed/fruit	*Triticum aestivum*	Martí 2011
Cova de les Cendres	East	Beta142288	6340	70		EN	Seed/fruit	*Hordeum vulgare*	Bernabeu and Molina 2009
Cova Bonica	Northeast	OxA26062	6340	34	−25.8	EN	Charcoal Short	*Arbustus Unedo*	Martins et al. 2015
Cariguela	South	Col1564	6316	39		EN	Animal bone	Ovis	Medved 2013
La Revilla del Campo	Ebro	UtC13347	6313	48		EN	Seed/fruit	Cereal	Rojo et al. 2012
Cova de l'Or	East	OxA10192	6310	70		EN	Seed/fruit	*Triticum aestivum*	Martí 2011
Font Major	Northeast	Beta317705	6310	40		EN	Animal bone	Ovis/capra	Cebrià et al. 2014
Los Castillejos	South	Ua36215	6310	45		EN	Cereal	Human bone	Martinez et al. 2011
Cova de la Sarsa	East	OxA31629	6309	36		EN	Human bone		Olalde et al. 2015
Hostal Guadalupe	South	Wk25169	6298	30		EN	Human bone	Human bone	Cortés et al. 2012
Sant Pau del Camp	Northeast	Beta236174	6290	50		EN	Animal bone	Ovis	Rojo et al. 2012
La Revilla del Campo	Ebro	KIA21351	6289	31		EN	Animal bone		Rojo et al. 2012
Cova dels Trocs	Ebro	Mams16163	6285	25		EN	Human bone	Human bone	Rojo et al. 2013
Cova de les Cendres	East	Beta107405	6280	70		EN	Animal bone	*Ovis Aries*	Bernabeu and Molina 2009
La Lampara	Ebro	KIA21352	6280	33		EN	Animal bone		Rojo et al. 2012
La Lampara	Ebro	UtC13346	6280	50		EN	Seed/fruit	*Triticum monococcum*	Rojo et al. 2012
Cova dels Trocs	Ebro	Mams16159	6280	25		EN	Human bone	Human bone	Rojo et al. 2013
Cova de l'Or	East	Beta298124	6290	40		EN	Seed/fruit	*Triticum aestivum*	Martí 2011
La Revilla del Campo	Ebro	KIA21357	6271	31		EN	Animal bone		Rojo et al. 2012
La Draga	Northeast	Beta278255	6270	40		EN	Animal bone	Ovis/capra	Rojo et al. 2012

Cova de l'Or	East	OxA10191	6275	70		EN	Seed/fruit	*Triticum aestivum*	Martí 2011
Roca Chica	South	Ua34135	6265	60		EN	Seed/fruit	Cereal	Cortés et al. 2012
Cariguela	South	Pta9163	6260	20		EN	Human bone	Human bone	Rojo et al. 2012
Los Castillejos	South	Ua36214	6260	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Can Fiulà	Northeast	Beta280353	6260	40		EN	Animal bone	Ovis	Bernabeu et al. 2015
Cueva de Nerja	South	OxA26084	6254	33	−16.5	EN	Animal bone	Ovis/capra	Aura et al. 2013
Cueva de Nerja	South	OxA26083	6252	33	−16.5	EN	Animal bone	Ovis/capra	Aura et al. 2013
La Revilla del Campo	Ebro	UtC13269	6250	50		EN	Seed/fruit	Cereal	Rojo et al. 2012
La Revilla del Campo	Ebro	UtC13295	6250	50		EN	Seed/fruit	Cereal	Rojo et al. 2012
Sant Pau del Camp	Northeast	Beta236175	6250	40		EN	Animal bone	Ovis	Rojo et al. 2012
Hostal Guadalupe	South	Wk25167	6249	30		EN	Animal bone	Ovis/capra	Cortés et al. 2012
Cova dels Trocs	Ebro	Mams16164	6249	25		EN	Human bone	Human bone	Rojo et al. 2013
Cova dels Trocs	Ebro	Mams16168	6249	28		EN	Human bone	Human bone	Rojo et al. 2013
Cova del Vidre	East	OxA26065	6248	33	−19.6	EN	Animal bone	Ovis	Martins et al. 2015
La Revilla del Campo	Ebro	KIA21359	6245	34		EN	Animal bone	Sus	Rojo et al. 2012
Botiqueria dels Moros	East	GrA13270	6240	50		EN?	Animal bone		Utrilla et al. 2009
Cova d'en Pardo	East	Beta231877	6240	40		EN	Animal bone	Ovis/capra	Soler et al. 2011
La Revilla del Campo	Ebro	UtC13294	6240	50		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Castillejos	South	Ua36212	6240	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Husos I	Ebro	Beta161182	6240	60		EN	Animal bone		Rojo et al. 2012
Roca Chica	South	Wk27462	6234	30		EN	Animal bone	*Ovis Aries*	Cortés et al. 2012
Cova dels Trocs	Ebro	Mams16166	6234	28		EN	Human bone	Human bone	Rojo et al. 2013
Chaves	Ebro	GrA26912	6230	45		EN	Human bone	Human bone	Utrilla et al. 2009
La Revilla del Campo	Ebro	KIA21355	6230	30		EN	Animal bone		Rojo et al. 2012
Los Cascajos	Ebro	Ua24426	6230	50		EN	Hueso humano	Hueso humano	Rojo et al. 2012
Cariguela	South	Col1567	6225	39		EN	Animal bone	Ovis	Medved 2013
Cariguela	South	Col1561	6224	32		EN	Animal bone	Sus	Medved 2013
Atxoste	Ebro	GrA9789	6220	60		EN	Animal bone		Utrilla et al. 2009
Cueva de Nerja	South	OxA26081	6219	33	−17.5	EN	Animal bone	Ovis/capra	Aura et al. 2013
Cova dels Trocs	Ebro	Mams16162	6218	24		EN	Human bone	Human bone	Rojo et al. 2013
Cova dels Trocs	Ebro	Mams16161	6217	25		EN	Human bone	Human bone	Rojo et al. 2013
Cueva de Nerja	South	OxA26082	6214	35	−20.2	EN	Animal bone	Ovis/capra	Aura et al. 2013
La Revilla del Campo	Ebro	UtC13350	6210	60		EN	Seed/fruit	Cereal	Rojo et al. 2012
Cueva de Nerja	South	OxA26079	6207	32	−17.1	EN	Animal bone	Ovis/capra	Aura et al. 2013
La Revilla del Campo	Ebro	KIA21346	6202	31		EN	Animal bone		Rojo et al. 2012
Cova de l'Or	East	Beta298126	6200	40		EN	Seed/fruit	*Triticum aestivum*	Martí 2011
Cova Foradada	Northeast	Beta248524	6200	40		EN	Human bone	Human bone	Cebrià et al. 2014
Cueva Murciélagos	South	Beta316509	6200	40		EN	Seed/fruit	*Hordeum vulgare*	Peña Chocarro et al. 2013
Cueva Murciélagos	South	OxA15648	6199	36		EN	Seed/fruit	*Hordeum vulgare*	Peña Chocarro et al. 2013

Table 1 (*Continued*)

Site	Area	IDLAB	BP	SD	$\delta^{13}C$	Phase	Material	Kind	Reference
Cueva de los Mármoles	South	Wk25171	6198	31		EN	Seed/fruit	*Hordeum vulgare*	Peña Chocarro et al. 2013
Hostal Guadalupe	South	Wk25168	6197	35		EN	Seed/fruit	*Hordeum vulgare*	Cortés et al. 2012
Cueva de Nerja	South	OxA26080	6196	31	–19.7	EN	Animal bone	Ovis/capra	Aura et al. 2013
Cueva Murciélagos	South	OxA15647	6192	35		EN	Seed/fruit	*Hordeum vulgare*	Peña Chocarro et al. 2013
Hostal Guadalupe	South	Ua34136	6190	50		EN	Seed/fruit	*Hordeum vulgare*	Cortés et al. 2012
Los Cascajos	Ebro	Ua16024	6185	75		EN	Human bone	Human bone	Rojo et al. 2012
Roca Chica	South	Wk25172	6185	30		EN	Seed/fruit	*Hordeum vulgare*	Cortés et al. 2012
Cueva Murciélagos	South	OxA15646	6184	35		EN	Seed/fruit	*Hordeum/triticum*	Carvalho et al. 2013
Cova del Vidre	East	OxA26064	6181	35	–19.4	EN	Animal bone	*Ovis Aries*	Martins et al. 2015
Cueva de los Mármoles	South	Beta313472	6180	40		EN	Seed/fruit	*Triticum aestivum*	Peña Chocarro et al. 2013
Cueva de los Mármoles	South	Beta313473	6180	30		EN	Seed/fruit	*Triticum aestivum*	Peña Chocarro et al. 2013
La Draga	Northeast	OxA20233	6179	33		EN	Seed/fruit	Cereal	Rojo et al. 2012
La Revilla del Campo	Ebro	KIA21354	6177	31		EN	Animal bone	Ovis/capra	Rojo et al. 2012
Cueva Murciélagos	South	OxA15650	6170	37		EN	Seed/fruit	*Hordeum vulgare*	Peña Chocarro et al. 2013
La Draga	Northeast	Beta278256	6170	40		EN	Animal bone	Ovis/capra	Rojo et al. 2012
Cova Colomera	Northeast	OxA23634	6170	30		EN	Seed/fruit	*Triticum aestivum*	Oms et al. 2014
Cova del Frare	Northeast	Beta325690	6170	40	–20.4	EN	Animal bone	*Ovis Aries*	Martins et al. 2015
La Draga	Northeast	OxA20231	6163	31		EN	Seed/fruit	Cereal	Rojo et al. 2012
La Revilla del Campo	Ebro	KIA21349	6158	31		EN	Animal bone		Rojo et al. 2012
Cova Bonica	Northeast	OxA6158	6158	32		EN	Animal bone	Ovis	Bernabeu et al. 2015
La Revilla del Campo	Ebro	KIA21353	6156	33		EN	Animal bone	Ovis/capra	Rojo et al. 2012
Los Castillejos	South	Ua37835	6155	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Cova Colomera	Northeast	Beta240551	6150	40		EN	Seed/fruit	*Triticum aestivum*	Rojo et al. 2012
Cueva del Toro	South	Beta-341132	6150	30		EN	Seed/fruit	*Triticum aestivum*	Camalich et al. 2013
La Lampara	Ebro	KIA6740	6144	46		EN	Human bone	Human bone	Rojo et al. 2012
La Lampara	Ebro	KIA6790	6144	46		EN	Human bone	Human bone	Rojo et al. 2012
La Draga	Northeast	OxA20235	6143	33		EN	Seed/fruit		Rojo et al. 2012
Cueva Murciélagos	South	Beta313477	6140	40		EN	Seed/fruit	*Triticum aestivum*	Peña Chocarro et al. 2013
Los Castillejos	South	Ua37844	6140	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Mas d'Is	East	Beta331019	6140	30		EN	Animal bone	*Bos taurus*	Bernabeu et al. 2014
Los Castillejos	South	Ua37839	6130	50		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Husos I	Ebro	Beta161180	6130	60		EN	Animal bone	?	Rojo et al. 2012
La Draga	Northeast	Oxa20234	6127	33		EN	Seed/fruit	?	Rojo et al. 2012
La Lampara	Ebro	KIA21348	6125	33		EN	Animal bone	*Bos primigenius*	Rojo et al. 2012
La Draga	Northeast	Oxa20232	6121	33		EN	Seed/fruit	?	Rojo et al. 2012

La Revilla del Campo	Ebro	UtC13348	6120	60		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Castillejos	South	Ua36208	6120	40		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Castillejos	South	Ua36213	6120	40		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Castillejos	South	Ua36203	6115	40		EN	Seed/fruit	Cereal	Rojo et al. 2012
Cueva Murciélagos	South	Beta313476	6110	40		EN	Seed/fruit	*Triticum aestivum*	Peña Chocarro et al. 2013
Cueva del Toro	South	Beta341131	6110	30		EN	Seed/fruit	*Hordeum vulgare*	Camalich et al. 2013
Cueva de los Mármoles	South	Beta313470	6100	40		EN	Seed/fruit	*Triticum aestivum*	Peña Chocarro et al. 2013
Los Castillejos	South	Ua36210	6100	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Castillejos	South	Ua37838	6095	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Los Castillejos	South	Ua36209	6090	40		EN	Seed/fruit	Cereal	Rojo et al. 2012
Paternanbidea	Ebro	GrA13673	6090	40		EN	Human bone	Human bone	Utrilla et al. 2009
Valmayor XI	East	Beta341167	6090	30		GM?	Animal bone		Rojo et al. 2015
Los Castillejos	South	Ua37834	6085	45		EN	Seed/fruit	Cereal	Rojo et al. 2012
Cova dels Trocs	Ebro	Beta316512	6080	40		EN	Seed/fruit	Cereal	Rojo et al. 2013
Cova dels Trocs	Ebro	Beta284150	6070	40		EN	Seed/fruit	Cereal	Rojo et al. 2013
Cova del Frare	Northeast	Beta325688	6070	30	–19.1	EN	Animal bone	*Ovis Aries*	Martins et al. 2015
Los Castillejos	South	Ua37837	6065	50		EN	Seed/fruit	Cereal	Rojo et al. 2012
Cova dels Trocs	Ebro	Beta295782	6060	40		EN	Animal bone		Rojo et al. 2013
Cueva Murciélagos	South	OxA15649	6056	35		EN	Seed/fruit	*Hordeum vulgare*	Peña Chocarro et al. 2013
La Lampara	Ebro	KIA6789	6055	34		EN	Human bone	Human bone	Rojo et al. 2012
Cueva de Nerja	South	Beta284147	6050	40		EN	Seed/fruit	Hordeum sp	Aura et al. 2013
Los Husos II	Ebro	Beta221640	6050	40		EN	Animal bone		Rojo et al. 2012
Cova dels Trocs	Ebro	Beta316514	6050	40		EN	Seed/fruit	Semilla	Rojo et al. 2013
Botiqueria de los Moros	East	GrA13268	6040	50		EN?	Animal bone		Utrilla et al. 2009
Los Husos II	Ebro	Beta221642	6040	40		EN	Animal bone		Rojo et al. 2012
Pou Nou 3	Northeast	OxA26066	6033	36	–19.7	EN	Animal bone	Ovis capra	Martins et al. 2015
Cerro Virtud	East	OxA6714	6030	55		EN	Human bone	Human bone	Rojo et al. 2012
Mas d'Is	East	Beta331018	6030	30		EN	Animal bone	*Bos taurus*	Bernabeu et al. 2014
Cingle Mas Cremat	East	Beta232340	6020	50	–21.4	EN	Seed/fruit	*Sorbus sp*	Rojo et al. 2012
Cova Gran	Northeast	Beta265982	6020	50		EN	Seed/fruit	*Acorn*	Bernabeu et al. 2015
Cova del Frare	Northeast	Beta325687	6020	40	–20.1	EN	Animal bone	*Ovis Aries*	Martins et al. 2015
Pou Nou 3	Northeast	OxA26067	6009	32	–19.2	EN	Animal bone	Ovis capra	Martins et al. 2015
Cova de Sant Llorenç	Northeast	OxA26072	6004	32	–19.7	EN	Animal bone	Ovis capra	Martins et al. 2015

identified as coming from short-lived plants), to help control for the possibility of post-depositional disturbance to archaeological deposits. The presence/absence of domestic species at a site constitutes the premise for determining Neolithic or Mesolithic status.

Table 1 shows the detail of the total number of dates (2016) used here. The start of the Final Mesolithic is taken from the most ancient published date clearly associated with human activity (*Cueva de la Cocina* Beta-267440, 7610 ± 40 uncalibrated BP: wild goat bone with processing marks). Several dates relating to the end of Mesolithic occupations and the first Neolithic evidence merit special consideration:

Mendandia Ua-34366 (7265 ± 60 BP), level III sup., is from a sample identified originally as aurochs, in a level with pottery but without other domestic elements. Although recent mtDNA analysis of this bone suggests the possibility that it is domestic (Alday 2012), we remain cautious due the absence of any other domesticates at the site. We group this with Mesolithic sites.

Forcas II Beta-247404 (6750 ± 40 BP) and Beta-247405 (6740 ± 40 BP) are from two levels with pottery but without domestic elements, and are therefore also considered as Mesolithic.

Carigüela Col-1565 (6749 ± 39 BP), level XVI—a sample identified as domestic cattle—provides the most ancient Neolithic date in Iberia. This date is part of a series of dates from Neolithic levels recovered from older excavations at this site, which is located in the southern region of Iberia (Mevdev 2013). This series also produced an even older radiocarbon date Coll-1563 (6950, 40) identified as a sheep/goat, but located in a typologically Middle Neolithic level. OxA-1131 (7010 ± 40 BP) is another anomalous date from Carigüela taken from a single sample of a wild horse, from level XV of the older excavations (Carrasco et al. 2010). These two earlier dates do not agree with the general chronology of Neolithic expansion elsewhere in the Western Mediterranean. On the other hand, no Mesolithic elements have been identified at the site so far. This suggests a need for a thorough reanalysis of the stratigraphic and archaeological context of the early excavations at the site. For these reasons, we only include *Col-1565* in our models.

Peña Larga Beta-242783 (6720 ± 40 BP) comes from a bone identified as domestic sheep/goat from a typologically Neolithic level (together with other domestic animals and pottery) of a site located in the Upper Ebro Valley (Fernández Eraso 2011). The result is surprising if we consider the oldest expected distribution of early radiocarbon dates from the Mediterranean coast.

Botiqueria GrA-13268 (6040 ± 50 BP) level 6 and GrA-13270 (6240 ± 50 BP) level 8, is associated with two stratigraphical units with impressed pottery separated from a Final Mesolithic level GrA-13267 (6830 ± 50 BP) by a sterile layer (Barandiarán and Cava 2002). No domestic taxa have been recognized, but the assemblage is of small size and poor quality. The presence of triangles and segments with bifacial retouches in units 6 and 8 also suggest late age, in the second half of the 6th millennium cal BC.

A similar case is observed for *Abrigo de Ángel 2*, Beta-254048 (6390 ± 40 BP) where only two fragments of pottery have been recovered (Domingo et al. 2010), in a similar context with segments and triangles with bifacial retouches characteristic of Neolithic sites. No faunal remains have been found except a few unidentifiable fragments of animal bones.

Valmayor II Beta-341168 (6570 ± 30 BP) and III Beta-341167 (6090 ± 30 BP) date two levels with a significant number of Early Neolithic sherds, and lithic remains similar to those in

Botiqueria and Angel 2 (Rojo et al. 2015). But in this case, the faunal remains have been identified as wild species. No domestic seeds have been recovered, despite a well-controlled excavation. Consequently, the authors consider this site as evidence for the acculturation of Mesolithic groups in the area (Rojo et al. 2015).

Botiqueria GrA-13268, GrA-13270, Ángel 2 *Beta-254048* and *Valmayor Beta-341168, Beta-341167* have been tested alternatively as Mesolithic or Neolithic in the models.

In this paper, we consider the Late/Final Mesolithic as a unit, although archaeological research distinguishes between an early phase where trapezes predominate and a final phase characterised by triangular armatures (Cocina type, similar to Muge type). The same consideration is applied to the Early Neolithic.

We present a dual scale of analysis: macro-regional and regional levels. The macro-regional level comprises a wide coastal region between the Pyrenees and Andalusia, encompassing Catalonia, Valencia, Murcia, and eastern Andalusia; along with the upper and middle Ebro Valley, including the southern Basque Country, Navarra, and Aragon (Figure 1). For the regional level analysis, we have used the major natural corridors mentioned above (Ebro River and the border of the coastal littoral) to divide the region into four main sub-areas. We have designated the areas as *northeast* (north of the Ebro River in Catalonia), *upper Ebro Valley* (north of the Aragon Ebro valley, Navarra region, and South Basque country), *east* (Catalonia south of the Ebro, lower Aragon, and the Valencian Autonomous region), and *south/southeast* (Murcia and Eastern Andalusia).

Calibration and Phase Modeling

In our analysis, we use Bayesian models as they have been implemented in Oxcal 4.2.4 (Bronk Ramsey 2009) to identify the beginning and end of two independent but overlapping phases within the neolithization process: Late/Final Mesolithic and Early Neolithic. The *Boundary* command identifies an event that has not been directly dated and estimates a probability distribution for its occurrence based on the known dates included in the phases preceeding and following the event (Bronk Ramsey 2009). The ^{14}C dates are not ordered stratigraphically, because they derive from different sites. The resulting start and end dates for each phase are presented with 1σ and 2σ ranges similar to calibrated ^{14}C dates. An agreement of 60.0 or higher is considered an acceptable result. We tested two models, using alternative interpretations of the recent ^{14}C dates from Botiquería levels 6 (GrA-13268) and 8 (GrA-13270), Abrigo de Ángel 2 (Beta-254048), Valmayor *II* and *III* (Beta-341168 and Beta-341167): as Neolithic (model A) or Mesolithic (model B).

We also examined regional variability in the modeled Mesolithic/Neolithic boundary for the upper/middle Ebro Valley and eastern region. Below, we discuss the chronological distinctions between the two phases (Mesolithic and Early Neolithic) and some problems linked with the differences detected in the regional archaeological contexts (i.e., information gaps).

Building Summed Probabilities Distributions of ^{14}C dates and Sites

With the idea of comparing trends in settlement patterns during the neolithization process, we use a method similar to common summed probabilities that includes a correction for the impact of different numbers of dates for different sites and levels. Alternative proposals for mitigate the impact of sites with multiple radiocarbon dating have been used in other works (Edinborough 2005; Shennan and Edinborough 2007; Edinborough 2008; see also Shennan et al. 2013 for a more refined method). Although an increasing number of archaeological studies use summed radiocarbon probability distributions (SCDPD) as a proxy for studying long-term prehistoric demography (Gamble et al. 2005; Collard et al. 2010; Shennan et al. 2013), indiscriminate use can present several problems (Bamforth and Grund 2012; Williams 2012; Combre and Robinson 2014). Nevertheless, some authors have developed robust protocols that allow supporting the use of SCDPD as an indicator for fluctuations in human population levels (Shennan et al. 2013; Timpson et al. 2014). The assumption of SCDPD analysis is that multiple small, unsystematic samples from a large sample of sites constitute a quasi-random sample of regional occupation trends. In this paper, we consider ^{14}C dates from short-lived and long-lived samples with a standard deviation of less than or equal to 100. We do not demand the same level of reliability as for the chronological model, because to observe trends we assume that an increased number of dates provides more robust results over a wider perspective. We include ^{14}C dates from the beginning of the Holocene until 6000 uncalibrated BP. In all we use a total of 402 dates. We calibrated all the dates using Oxcal Program 4.2.4 and IntCal13 curve for the Northern Hemisphere (Reimer et al. 2013) with 1σ (68.2). Then we distributed all dates within intervals of 200 yr. Finally, we selected and summed only one date per site per interval. In the discussion that follows, this is a salient point to add to the explanation over the chronological models constructed.

RESULTS

To quote Box (1979): "All models are wrong but some are useful." With that in mind, we try to interpret the results obtained, and to point out several aspects relevant to socioecological dynamics which can be explored through these Bayesian analyses (Whittle et al. 2011). We test the dual model building different scenarios in several scales of analysis (see Riede and Edinborough 2012; Burley et al. 2015). At the macro scale of the analysis, Model A has an acceptable agreement index of 73.7, while Model B has an agreement index of 59 (Table 2, and supplementary material) and consequently it cannot be considered acceptable. Model A considers Botiquería level 6 (GrA-13268) and 8 (GrA-13270), Abrigo de Ángel 2 (Beta-254048) and Valmayor II and III Beta-341168 and Beta-341167 as Neolithic samples. Therefore, in this model we do not consider the absence of domestic elements as a definitive indicator of a Mesolithic occupation.

If this seems to contradict our prior assumptions regarding Neolithic and Mesolithic status (mentioned above), in reality it serves to highlight the temporal distance between the latest Mesolithic ^{14}C date in Botiqueria (GrA-13267, 6830 ± 50) and the first Neolithic dates (GrA13270, 6240 ± 50), and reflects a possible gap in human occupation indicated by the excavators (Barandiarán and Cava 2001). In our opinion these arguments reinforce the results of Model A versus model B. On the other hand, both models present problems with the agreement index for the following dates: Col-1565 (6749 ± 39) and Beta-242783 (6720 ± 40) with an index of 6.2 and 27.4 for model A, and 7 and 30.4 for model B. Treating the date Beta-341167 and Botiquería date GrA-13268 (6040 ± 50) as Mesolithic also fails, with an index of 51.6 and 33.4. Both, *Col-1565* (6749 ± 39) and Beta-242783 (6720 ± 40) ^{14}C dates, then, are probably best considered the most ancient dates for Neolithic contexts in Iberia. *Col-l565* corresponds to a cattle bone located at the bottom of the Neolithic levels in Carigüela, of the southern region (Mevdev 2013). Unfortunately, no detailed publication is yet available for this interesting cave, which presents one of the most complete assemblage series of impressed pottery in southern Iberia (Navarrete 1976; Mevdev 2013). Currently, it is not possible to evaluate the evidence from this site. Recent ^{14}C analyses suggest caution in interpreting certain ^{14}C dates, such as Col-1563 (6950 ± 40) and OxA-1131 (7010 ± 40), due to problems linked with the

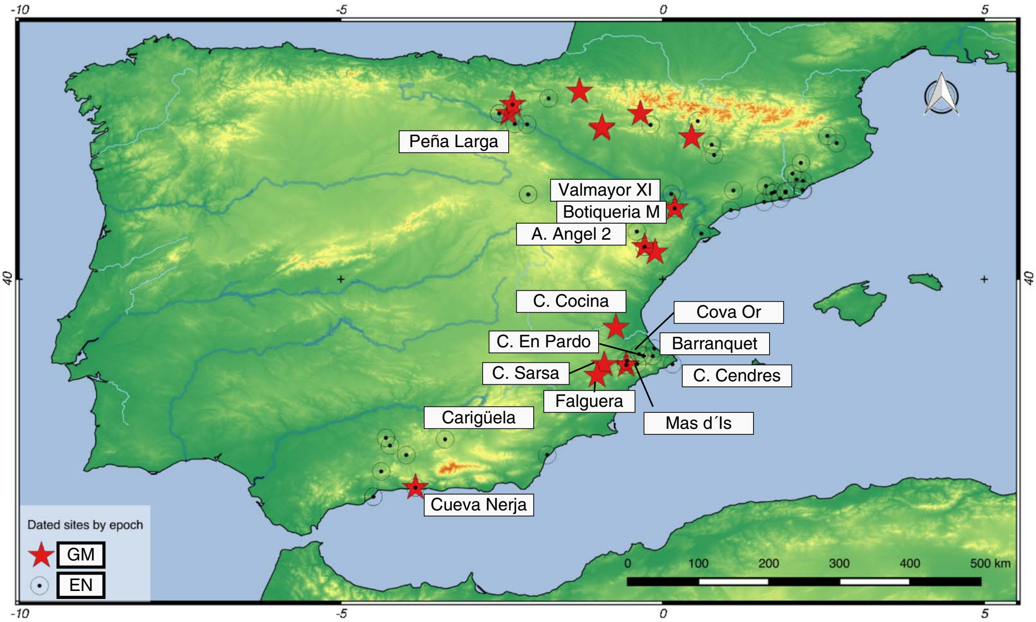

Figure 2 Mesolithic and Neolithic sites in Mediterranean Iberia region used for chronological modeling.

sample identification (sheep/goat) and/or with the cultural associations of the samples (Mevdev 2013). Alternatively, some problems linked with bone dating protocols could be considered (Wood 2015). While this sample could be associated with pre-Neolithic occupations, we have not yet discarded Col-1565 (6749 ± 39), because it is close in age to other early Neolithic contexts in Iberia.

Beta-242783 (6720 ± 40) corresponds to a sheep/goat sample date found at the Peña Larga rock shelter in the upper Ebro valley (Figure 2). This merits a special mention due to its location in an inland area distant from the Mediterranean Sea and along a main corridor for Neolithic expansion. Accepting this date implies a rapid neolithization process via different inland routes and not only along the Mediterranean coast as suggested by Zilhao (2001, 2011). Alternatively, a combination of taphonomic and/or technical problems affecting the ^{14}C sample could be responsible for this result. For the time being, we consider the date valid, while awaiting further clarifying information, as there are no immediately apparent problems with the calibration curve.

We applied the overlapping model in two regional sub-areas: the upper-middle Ebro valley and the eastern coast of Iberia. Regional models have only been constructed for these two sub-areas, due to the absence of late Mesolithic deposits in the northern (Catalonia) sub-region and the Murcia/eastern Andalusia sub-region. The overlapping model in the upper-middle Ebro valley has an overall agreement index of 91.2, which constitutes a good result and indicates the consistency of the model (Figure 3). The date of Peña Larga (Beta-242783, 6720 ± 40) shows a low agreement (28.1), which again highlights its distinct context discussed above. As we did for the entire area, we consider two hypotheses (A and B) for the Eastern region. In this case Model A considers Botiquería levels 6 (GrA-13268) and 8 (GrA-13270), Abrigo de Ángel 2 (Beta-254048) and Valmayor II and III (Beta-341168 and Beta-341167) as Neolithic, while Model B considers the same dates as Mesolithic dates. Model A in the Eastern region generates

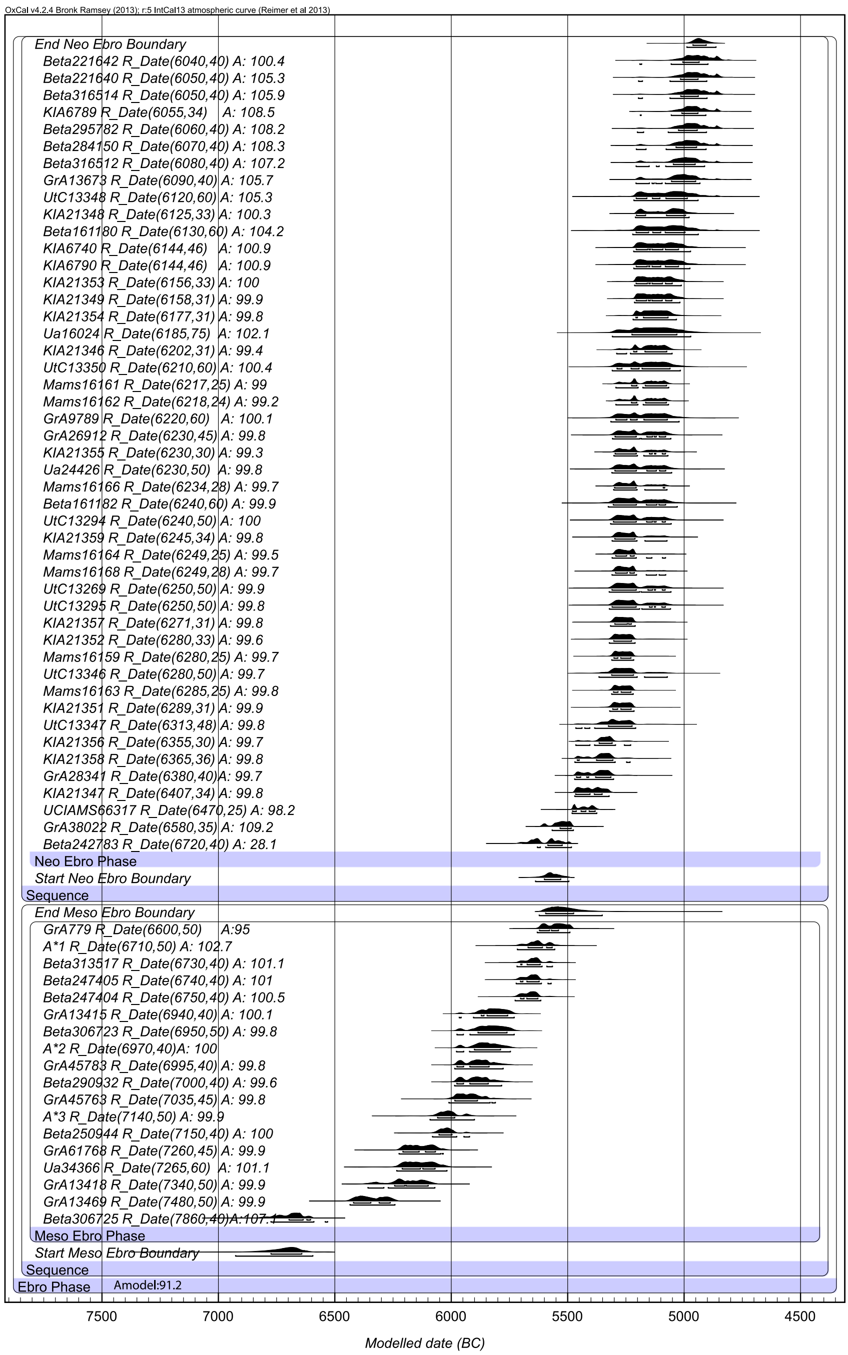

Figure 3 Phase modeling results showing the probability distributions of radiocarbon dates for Mesolithic and Neolithic overlapping phases in the Ebro valley region.

the larger agreement index value (Amodel 99), although both present acceptable index values (Figure 4). The most ancient Neolithic date in this region is En Pardo (Beta-231880, 6660 ± 40) (Soler et al. 2013). Model B has an agreement index of 90.4 (Figure 5).

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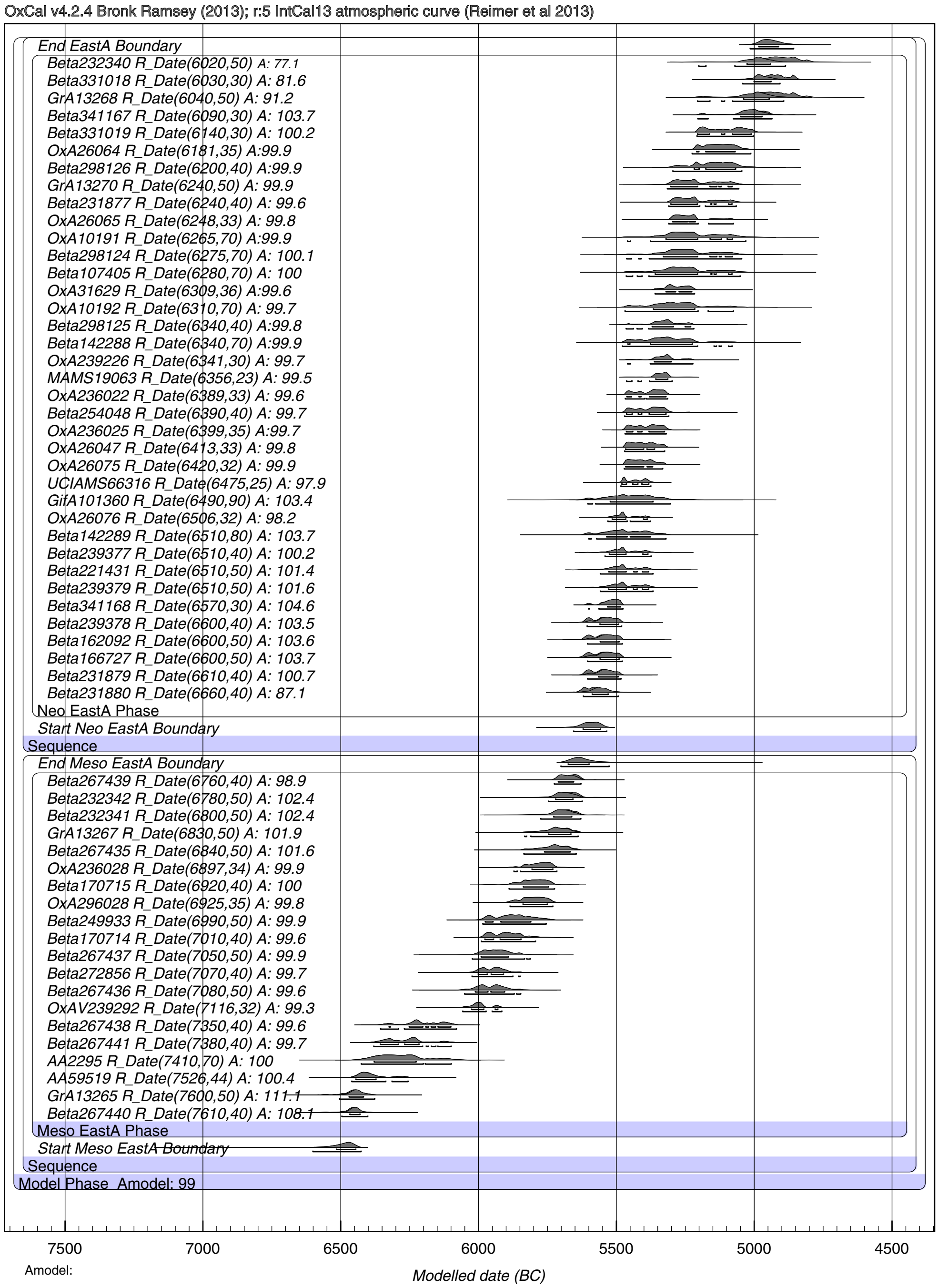

Figure 4 Phase modeling results showing the probability distributions of radiocarbon dates for Mesolithic and Neolithic overlapping phases in the Eastern area (model A).

Overall, the general models that reflect the validity of hypothesis A (Botiquería, Ángel 2 and Valmayor as Neolithic occupations) are more robust than those of hypothesis B (Table 2 and Figure 6). Accepting hypothesis A implies the coexistence of Mesolithic and Neolithic societies.

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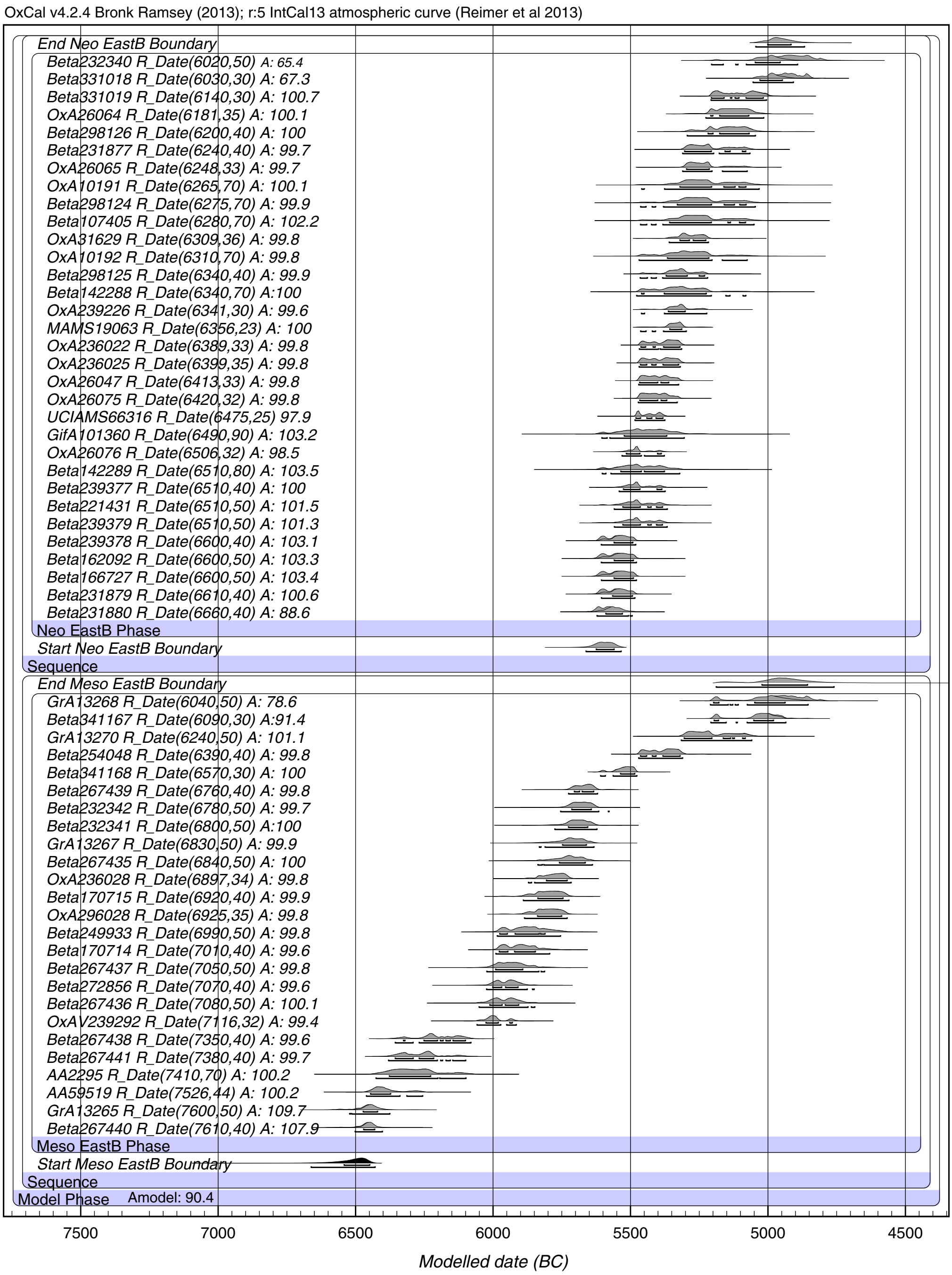

Figure 5 Phase modeling results showing the probability distributions of radiocarbon dates for Mesolithic and Neolithic overlapping phases in the Eastern area (model B).

But thereafter (Table 3 and Figure 6) it is not possible to follow their immediate evolution from the current archaeological record. Model B reflects an even longer time span of coexistence, although the resolution of the stratigraphic context remains a challenge. On a regional level, the

Table 2 Bayesian sequence modeled dates from Oxcal 4.2.3 (Bronk Ramsey 2009). Calibration conducted using IntCal13 curve: Northern Hemisphere (Reimer et al. 2013).

Models	Nr of dates	Mesolithic	Neolithic	A_{model}	$A_{overall}$
A, general	215	40	175	73.7	76.3
B, general	215	45	170	59	68.8
A, East	57	20	37	99	96.8
B, East	57	25	32	90.4	87.9
Ebro	64	17	47	91.2	92.7

Table 3 Bayesian sequence modeled dates from Oxcal 4.2.3 (Bronk Ramsey 2009). Interval span and distance between the end of the Mesolithic and the start of the Neolithic. Calibration conducted using IntCal13 curve: Northern Hemisphere (Reimer et al. 2013).

Models	Interval	1C	2C	Min distance 1C	Max distance 2C
A, general	End Meso	5617–5559	5633–5505		
	Start Neo	5588–5560	5596–5538	–29	33
B, general	End Meso	5193–4960	5198–4907		
	Start Neo	5591–5561	5600–5540	398	633
A, East	End Meso	5675–5600	5702–5527		
	Start Neo	5621–5558	5656–5536	–54	9
B, East	End Meso	5022–4857	5189–4760		
	Start Neo	5625–5560	5662–5535	603	775
Ebro	End Meso	5595–5475	5623–5352		
	Start Neo	5601–5531	5639–5496	6	144

models offer more robust results. The Ebro model presents a consistent model where the coexistence between Mesolithic and Neolithic groups is more visible from ^{14}C (DistMin/Max = 6/144) (Table 3 and Figure 6). In the Eastern area, the possibility of recognizing an acculturation process through ^{14}C dates is not well reflected by Model A (more robust Amodel: 99).

Consequently, we feel this suggests that coexistence of Mesolithic hunter/gatherers and Neolithic farmers is possible even though not well reflected in the archaeological record. The regional variability reinforces this conclusion, and highlights regional differences between the Mediterranean corridor (a quick Neolithic expansion) and the Ebro valley (where acculturation processes had a greater opportunity).

As a complementary analysis to better understand trends in socioecological dynamics among the last hunter gatherers and first farmers in Mediterranean Iberia, we combined all filtered radiocarbon dates (single fragments, short-lived taxa, SC < 100) for the Mediterranean region into a SCDPD curve (Figure 7). We compare this curve with a curve of the number of distinct occupations dated to each 200-yr interval throughout the same region. Although there are relatively fewer sites than dates for the later Neolithic, both datasets display similar patterns. An interesting consideration is the increase of dates coincident with the beginning of the Late Mesolithic (Figure 7) associated with the appearance of standardized blade technology and trapezes (Martí et al. 2009; Binder et al. 2012). The peaks in both curves show when the Neolithic is well in evidence over much of the Iberian Peninsula (ca. 5300 cal BC) (Bernabeu and Martí 2014; Bernabeu et al. 2014).

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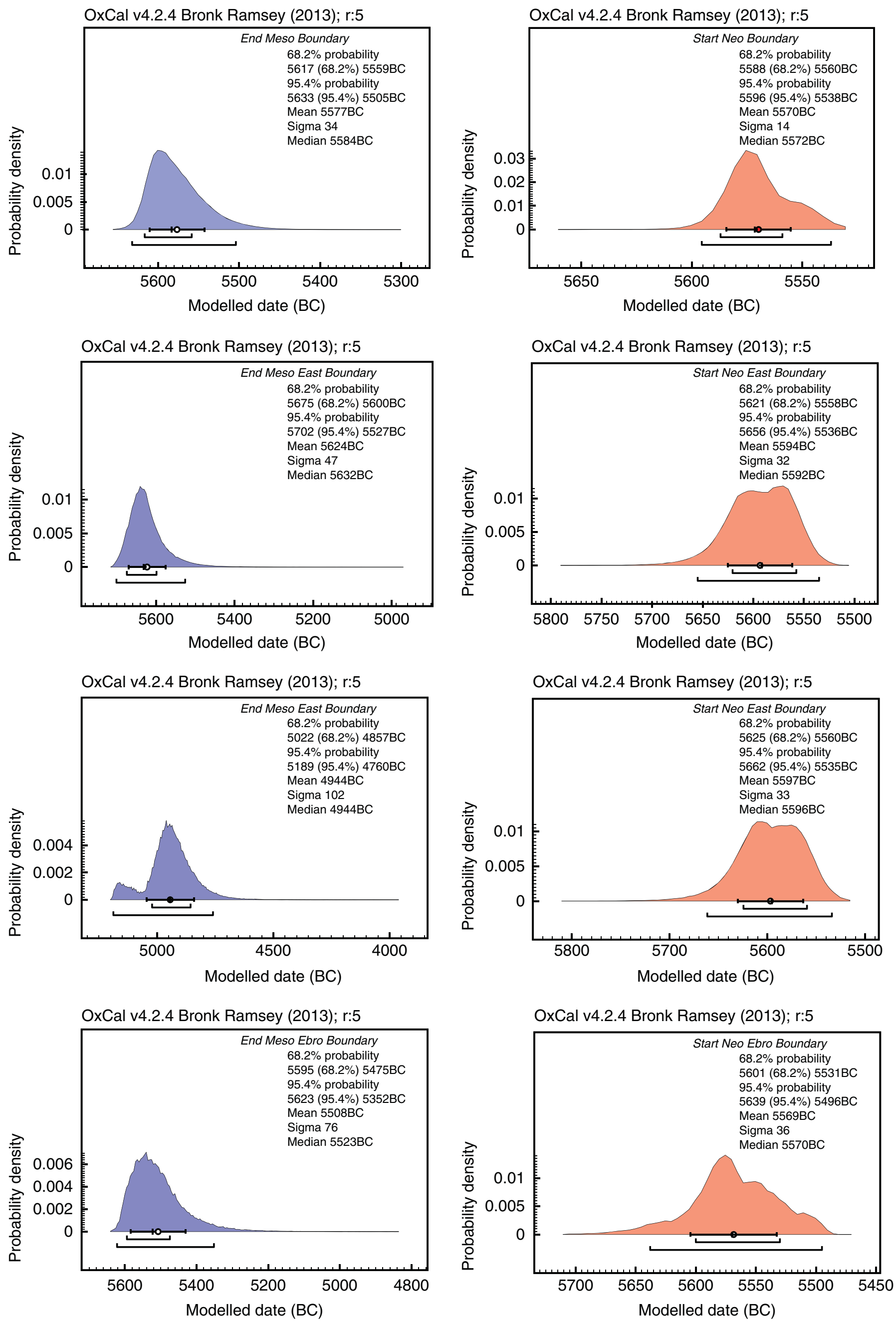

Figure 6 Phase modeling results showing the end of the Mesolithic and the beginning of the Neolithic according with the different models proposed (general A model, and regional models: Eastern A and B models, and Ebro model).

The ^{14}C curve begins a steep climb around 5700 cal BC, with the arrival of the Neolithic to the region. That is, a substantial change in ^{14}C densities is coincident with the introduction and expansion of agricultural practices associated with the initial appearance of the Neolithic.

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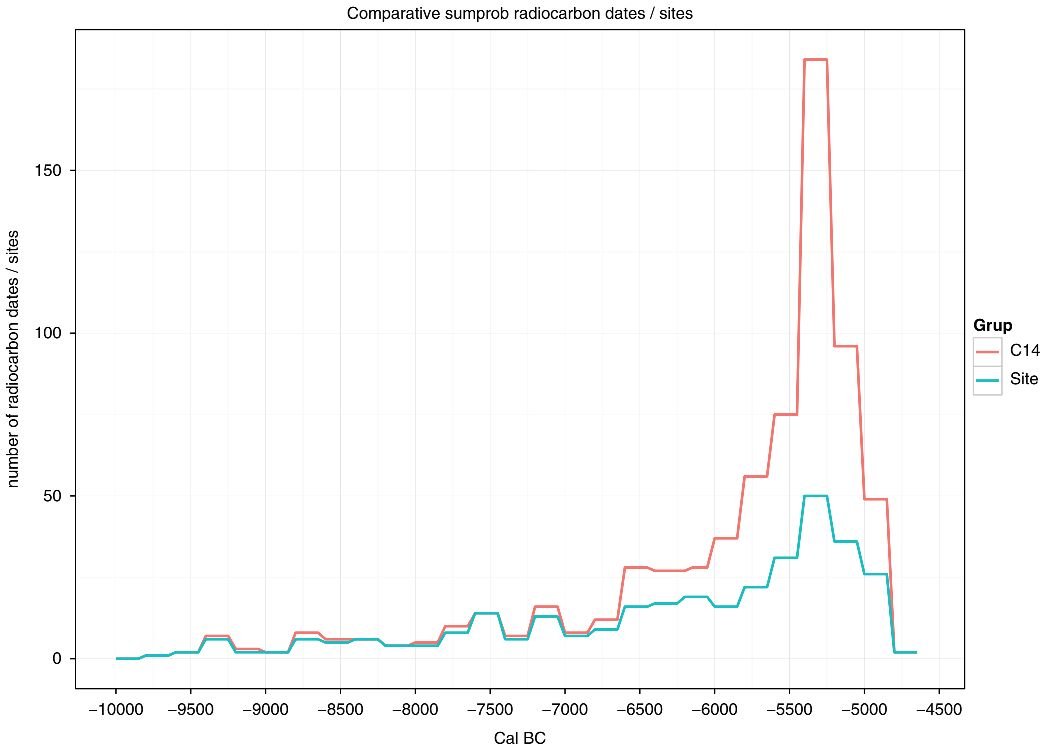

Figure 7 Comparative sumprob radiocarbon dates/sites distributed within intervals of 200 years. We calibrated all the dates using Oxcal Program 4.2 and IntCal13 curve for the Northern Hemisphere (Reimer et al. 2013) with 1σ (68.2).

DISCUSSION

As pointed out by Bocquet-Appel (2008), indicators of demographic transition have been detected around the world at the beginning of the Neolithic, linking the increase of population to the new modes of subsistence and residential patterns. A growing number of researchers have used the density curves of large series of radiocarbon data as a viable proxy for these signals (Gamble et al. 2005; Shennan and Edinborough 2007; Shennan et al. 2013).

Recent studies use this information as demographic proxies at different geographical levels in Europe (Shennan and Ediborough 2007) as well as to show trends of settlement densities (Bernabeu et al. 2014; Bernabeu et al. 2015b). The results presented here indicate the clarity of this signal for the Mediterranean Iberian region, where the arrival of agriculture and husbandry coincides with a rapid increase in radiocarbon densities—a pattern that is also observed in other European regions (Shennan et al. 2013; Timpson et al. 2014).

The general debate in Europe about the social processes responsible for the Neolithic transition centers on the importance of demic expansion (see Ammerman and Cavalli Sforza 1984; Perles 2001; Zilhao 2001; Guilaine 2001; Ammerman and Biagi 2003; Forenbaher and Miracle 2006; Guilaine and Manen et al. 2007; Robb 2007; Bernabeu et al. 2009; Colledge et al. 2013; Ozdogan 2011; Rowley-Conwy 2011; Juan-Cabanilles and Garcia Puchol 2013; McClure 2013; McClure and Podrug 2016) and the pace of Neolithic expansion (Bocquet-Appel et al. 2012, Fort 2012). Despite the discussion about the interpretation of particular sites and dates

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(see Zilhao 2011; Alday 2012), or the respective impact of demic diffusion versus indigenous components (Bernabeu 2002; Zilhao 2003; García Puchol et al. 2009; Diaz del Río 2011; Cruz Berrocal 2012; Bernabeu and Martí 2014; Isern et al. 2014; Bernabeu et al. 2015a, 2015b), general agreement exists among researchers in the Iberian Peninsula on the existence of an initial impact of foreign components and the hypothesis of dual drivers of demic expansion and acculturation. In accordance with the dual model proposal we assume that an initial foreign expansion constituted the driving force of the subsequent spread in Iberia.

Chronological analysis using a Bayesian approach allows the exploration of alternative hypotheses about dual demic/acculturation models. In this respect, several points are worth noting. One concerns the latest Mesolithic context considered. We tested two possibilities for the cultural affiliations of several ambiguous dates from sites in the eastern region: Botiqueria, Angel 2, Valmayor II and III. The Bayesian models indicate a more probable Neolithic affiliation for these dated contexts. The existence of a chronological gap between Mesolithic and Neolithic levels in Botiqueria reinforce this interpretation. This would make Aizpea *GrA-779* (6600, 50) (Cava 1997) the last authenticated Mesolithic date currently known. Other dates position the initial Neolithic expansion in Iberia at around 5650 cal BC (*Col-1565,* 6749 ± 39: 5725–5575 cal BC; *Beta-242783,* 6720 ± 40: 5715–5561 cal BC; *OxA-26068,* 6655 ± 45: 5644–5491 cal BC, 2σ range; Beta-131577, 6590 ± 40: 5616–5481), all based on bones of possibly domestic animals, although some problems can be highlighted about their domestic status only confirmed for Beta-131577 (Cueva de Nerja, in southern Iberia) (Martins et al. 2015). The oldest domestic seed corresponds to Mas d'Is (Beta-162092, 6600 ± 40, 5617–5485 cal BC), an open-air site located in Eastern Iberia region (Bernabeu et al. 2014). Their wide distribution around the region fuels debate about the existence of different entry routes of Neolithic farmers coming from the north and from the south along the Iberian coast (García Borja et al. 2014).

CONCLUSION

We have tested alternative variants of the dual model, a mixed model that proposes the coexistence between migrant farmers and Mesolithic groups during the Neolithic arrival in Mediterranean Iberia. To do that we have used a large and carefully filtered radiocarbon dataset to compare a SCDPD method as a proxy for diachronic fluctuations in population levels of and Bayesian boundary modeling to examing the potential overlap in final Mesolithic and initial Neolithic occupations. We found variable support for Mesolithic acculturation at the scales of sub-regions and over all of Mediterranean Iberia. The most robust models do not support the existence of a lengthy acculturation process across the entire region, nor in the eastern sub-area. In the Ebro area, there is stronger support for a longer period of acculturation between Mesolithic and Neolithic groups. Although we were unable to construct sub-regional models for the northern (Catalonia) sub-region and the Murcia/eastern Andalusia sub-region, current archaeological data supports a model of Neolithic colonization in those areas.

The combined SCDPD curve built for the entire region of Mediterranean Iberia also sheds new light on discussions of neolithization. An initial increase in ^{14}C densities is linked with the appearance of blade technology and trapezes in the Mesolithic sequence in the region; a much more marked peak in the SCDPD curve corresponds with the first appearance of domestic remains. Consequently, we note that agro-pastoral practices significantly increased the densities—and possibly increased populations across the peninsula (see Figure 7). This rapid increase does not seem to reflect the kind of long-term acculturation process in Mediterranean Iberia as a whole observed in the archaeological record of other European regions (Collard et al. 2010; Rowley Conwy 2011).

The detection of necropoli from the Early Mesolithic onward in the area, indicates differences in settlement patterns that could reflect more residential stability, an aspect which also coincides with the increase in radiocarbon date densities. At the same time, the rise in the diversity of resources used is noted from the beginning of the Holocene in hunter-gatherer subsistence patterns (Martí et al. 2009), including sites located along coastal and wetland areas. Despite these data, current information does not seem to indicate high population levels. On the other hand, the signal detected in SCDPD at the beginning of the Neolithic could be linked with the hypothesis of a foreign introduction related to farming and herding practices by migrant farmers. The results of Bayesian boundary modeling offer support for some degree of regional variability in farmer-hunter interaction. A rapid assimilation seems to be the case in the east, and a longer coexistence in the Ebro valley. If this were the case, we would expect to find sites and layers with Mesolithic industries and some Neolithic artifacts, such as pottery. However, a more refined chronology is needed if we want to gain further insight into the problems relating to Mesolithic/Neolithic relationships.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2017.61

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